RESEARCH ON FOREST SOILS AND TREE NUTRITION

By H. G. MILLER and B. L. WILLIAMS
Macaulay Institute for Soil Research, Aberdeen

TREE NUTRITION

Nitrogen Nutrition of Pines

As described in previous *Reports* (1965 to 1969) a study has been made of the uptake and release of nutrients in a stand of Corsican pine at Culbin Forest (Moray). This stand, like much of the rest of the forest, had entered a phase of declining growth rate upon reaching middle-age, a condition that was found to be due to an increasingly severe deficiency of nitrogen resulting from the continuing immobilisation of this nutrient in the newly developing humus layer (Miller, 1969). In order to investigate some of the factors controlling the transformations of nitrogen in coniferous mor humus, and the uptake of nitrogen by trees, a new experiment has been laid out in a nitrogen-deficient 40-year-old crop of Scots pine at Culbin. In 1968 this experiment was treated with 250 kg of elemental nitrogen per ha applied as fertiliser forms of ammonium sulphate, sodium nitrate, ammonium nitrate and urea, these nitrogen treatments being partially factorialised with applications of triple superphosphate (to supply 100 kg phosphorus per ha) and ground limestone (2·5 tonnes per ha). The nitrogen treatments were re-applied in the spring of 1969, but no further applications of phosphorus or lime have been given.

By the end of the first growing season clear differences existed between the plots receiving the various forms of nitrogen. Needle weight and needle nitrogen concentration were highest in those plots given ammonium nitrate (29 mg and 2·5 per cent N, as against 20 mg and 1·4 per cent N in untreated trees) and both these parameters were significantly greater in the ammonium nitrate plots than in those given either sodium nitrate or urea (24 mg and 1·8 per cent N), with ammonium sulphate occupying an intermediate position (25 mg and 2·0 per cent N). After the second growing season, however, the differences in nitrogen concentration were very much reduced, the urea treatments, in particular, having shown a marked increase over the intervening twelve months. At this stage the needle nitrogen concentration was still highest in the ammonium nitrate treated trees (2·5 per cent N), followed by urea (2·3 per cent N), ammonium sulphate (2·25 per cent N) and sodium nitrate (2·15 per cent N). Phosphorus and lime had no significant effect on needle nitrogen concentration, at least over the first two years following application, but did tend to increase needle weight at any one foliar nitrogen level.

Humus samples were taken from this experiment for incubation studies in May 1969, prior to the second application of nitrogen fertiliser, and again late in the following August. The results of these studies are reported below.

Nutrient Content of Sitka Spruce

During the year a new study was initiated to determine the amount and distribution of dry matter and nutrients within a stand of 21-year-old Sitka spruce growing on thin hill peat at Fetteresso Forest (Kincardineshire). Preliminary work has been concerned with developing satisfactory means of sampling and subsampling this species, the gross morphology of which is so different from that of pine that it has proved necessary to make extensive modifications to the techniques originally developed with Corsican pine. A small-scale trial sampling, taking only four trees, has been made to determine the degree and pattern of variation likely to be encountered in both the distribution of foliage and the foliar nutrient concentrations in these trees.

The weight values obtained from these four trees suggest that Sitka spruce carries a larger amount of foliage than does pine, possibly about 18 000 kg per ha in this experimental crop as against 14 000 kg per ha found on fast growing Corsican pine in a previous investigation. Maximum crown development consistently occurs in the region of internodes 4 to 7, numbering from the top, there apparently being little difference in this between tree sizes. As might be expected the concentrations of nitrogen, phosphorus, potassium and sodium in the foliage were found to decrease with increasing age of needle at any fixed level in the crown, whereas that of calcium increased. For any given age of needle, calcium concentration varied little down the length of the crown whereas the concentrations of nitrogen, phosphorus, potassium and sodium tended to decrease. However, at the very bottom of the crown there were marked increases in the concentrations of phosphorus, potassium and sodium, and a decrease in the concentration of calcium. Variations in magnesium concentrations showed no consistent trend.

A full-scale and intensive sampling of this crop is now under-way.

Effect of Shade on Nutrient Uptake

A short duration study has been initiated to check continental reports that shading of certain coniferous species results in increases in foliar nutrient and chlorophyll concentrations. Starting in November 1969, samples of foliage have been taken at monthly intervals from young Lodgepole pine, Sitka spruce, Douglas fir, Grand fir and Western hemlock planted beneath five densities (approximately 0, 100, 200, 300 and 500 stems per ha) of middle-age larch at Drumtochty Forest (Kincardineshire). At each sampling the concentration of chlorophyll has shown a marked and consistent increase with increasing shade, at least up to 300 stems per ha. Variations in nutrient levels are not so well defined but with some elements, particularly potassium, a distinct pattern appears to be developing with the approach of the growing season. The effect of increasing shade on the size of individual needles, in terms of their length, area and weight, varied with species, maximum values occurring beneath an over-canopy of 500 stems per ha with Douglas fir, beneath 300 stems per ha with hemlock, beneath 100 stems per ha with both spruce and Grand fir and in the open with pine. However, a microscopic examination of cross-sections of these needles gave no suggestion that any of these species is producing morphologically specialised "shade-needles" under the range of shade intensities being considered.

Mineralisation of Nitrogen in Peat and Humus

A new series of studies has been initiated to examine some of the factors, particularly those of the chemical environment, that affect release of

mineral nitrogen from coniferous mor humus and deep acid peats. Both mor humus and acid peats contain large quantities of organic nitrogen, yet the trees they support may become severely nitrogen-deficient. Preliminary investigations have been concerned with developing satisfactory incubation techniques to quantify, at least on a relative scale, the effect of various treatments on the rate of net production of inorganic nitrogen in these two forms of accumulated organic debris.

Incubations have been carried out at 30°C on samples of humus taken in early May and late August from the Scots pine experiment at Culbin described above. In May, just prior to the second application of nitrogen fertiliser to this experiment, between 0·2 and 4·4 per cent of the total nitrogen in the humus was in the inorganic form and therefore could be extracted with 2N KCl, whereas by late August inorganic nitrogen had risen to between 0·5 and 15·7 per cent of the total. On both occasions the higher values occurred in samples from those plots that had been given nitrogen fertiliser, and these were also the samples that gave the highest net production of additional mineral nitrogen on incubation for nine weeks. In samples from plots that had received nitrogen fertiliser, the quantity of mineral nitrogen present after incubation varied with form of nitrogen applied and tended to increase in the order: sodium nitrate <ammonium sulphate <ammonium nitrate <urea. The effect of lime, whether applied alone or in combination with phosphorus, was to depress net mineralisation in any nitrogen treatment. The response to phosphorus without lime, however, was variable, but at least in the May samples phosphorus tended to have a stimulatory effect on mineralisation.

Samples of peat for incubation studies were taken in September 1969 from drainage experiments on a raised bog at Achray Forest (Stirlingshire) and hill peat at Inchnacardoch Forest (Inverness-shire). The amounts of mineralised nitrogen in fresh samples was found to be very variable, the trend at both sites being an increase in inorganic nitrogen (almost wholly ammonium) with increasing moisture content of the peat. However, the quantities found in samples of the very poorly decomposed *Sphagnum* peat from the raised bog at Achray tended to be lower than the quantities of inorganic nitrogen found in samples of the more highly decomposed *Sphagnum-Trichophorum* hill peat of Inchnacardoch Forest. During incubation of samples from these two sites mineral nitrogen accumulated very slowly. The rate was particularly slow in samples from unfertilised peat at Inchnacardoch Forest: furthermore, mineralisation in these samples showed no relationship to the imposed drainage treatments. However, in samples from sections of the same plots that had been fertilised with N P and K the quantity of mineral nitrogen that could be extracted after incubation for nine weeks was greater and was found to increase with the decreases in moisture content brought about by the drainage treatments. Mineralisation in the samples from the experiment at Achray Forest showed little relation to drainage, but here again there was some evidence that an increased application of P and K could stimulate the net production of mineral nitrogen under the conditions of incubation used in this study.

REFERENCE

MILLER, H. G. (1969). Nitrogen nutrition of pines on the sands of Culbin Forest, Morayshire. *J. Sci. Fd Agric.* **20,** 417–419.